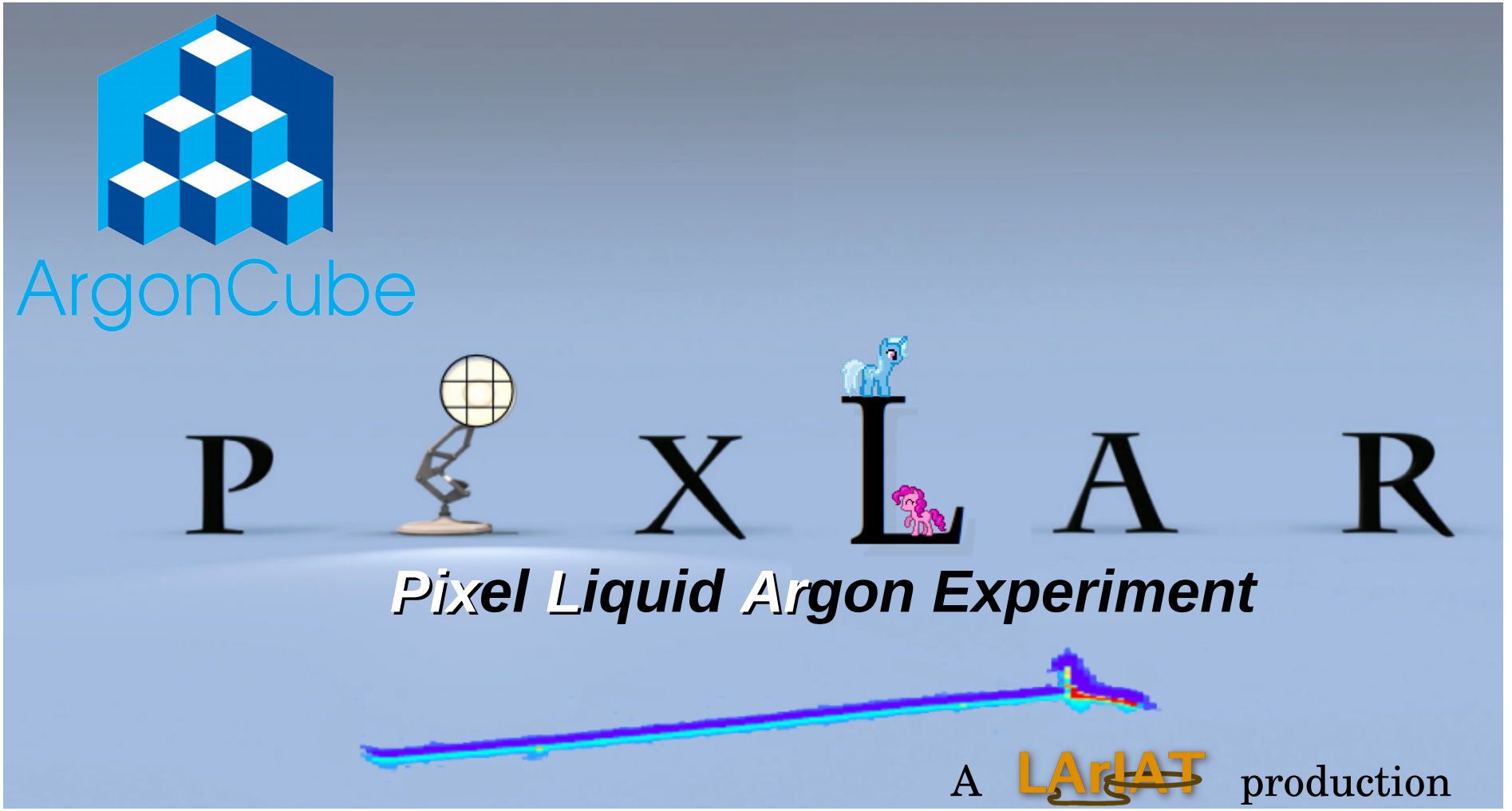
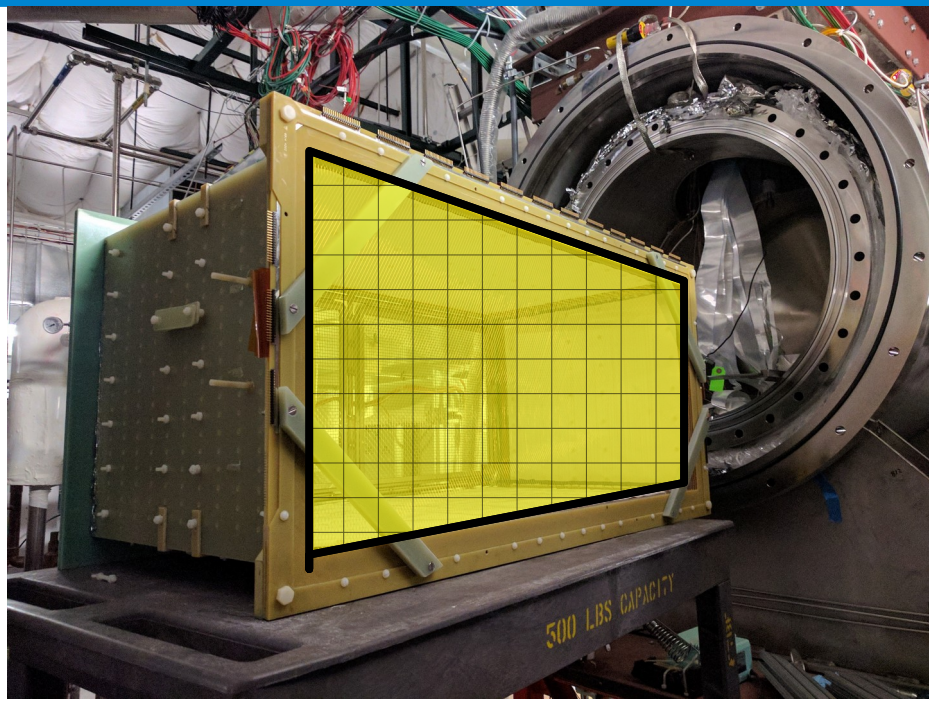
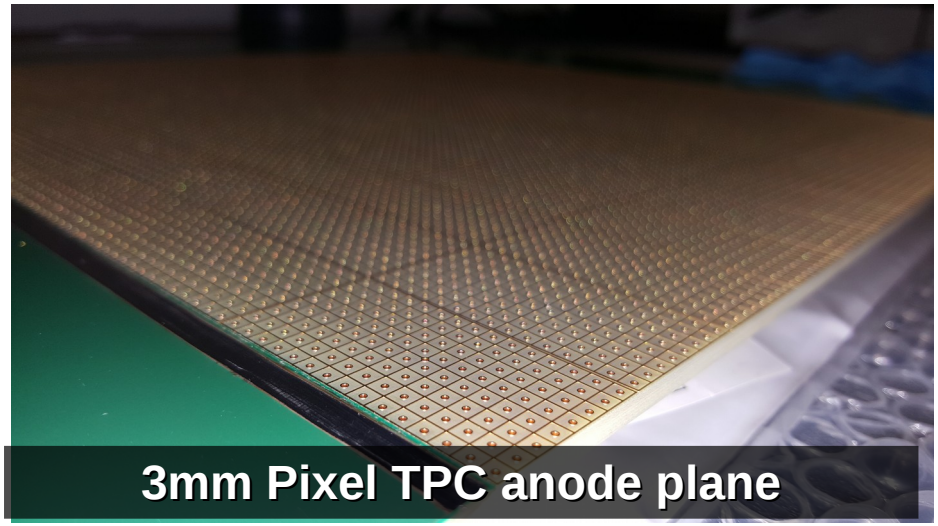


Jonathan Asaadi
UT Arlington
(On behalf of the PixLAr Collaboration)

What is PixLAr?

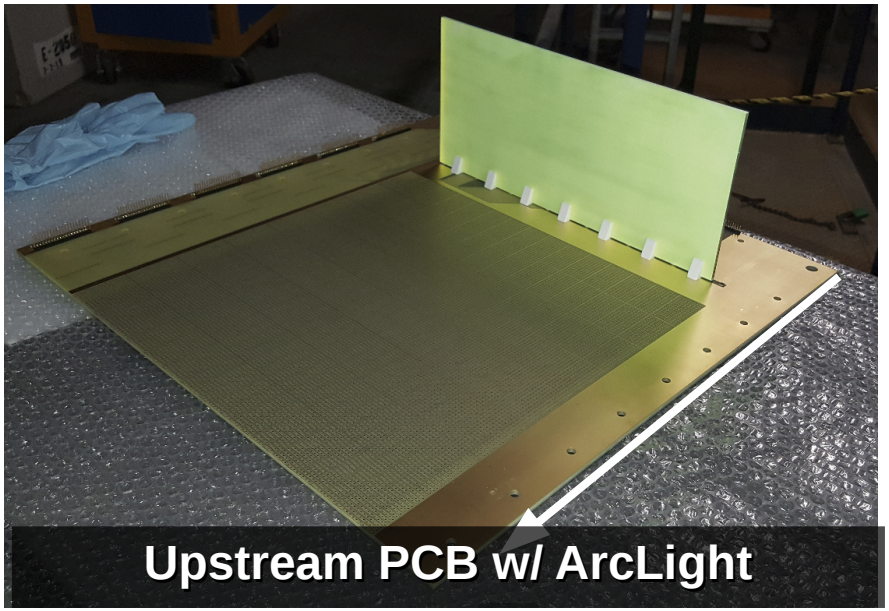
- **This is the latest incarnation of the LArIAT setup, but this time using a Pixel based readout for the charge**
  - This was done in the style of the Bern based Pixel TPC being considered as an option for the DUNE near detector
  - The pixel plane PCB based design routes to LArIAT's existing cold electronics
    - Use Regions of Interest (ROI's) and some multiplexing to readout a 28,800 pixels using LArIAT existing 480 channels

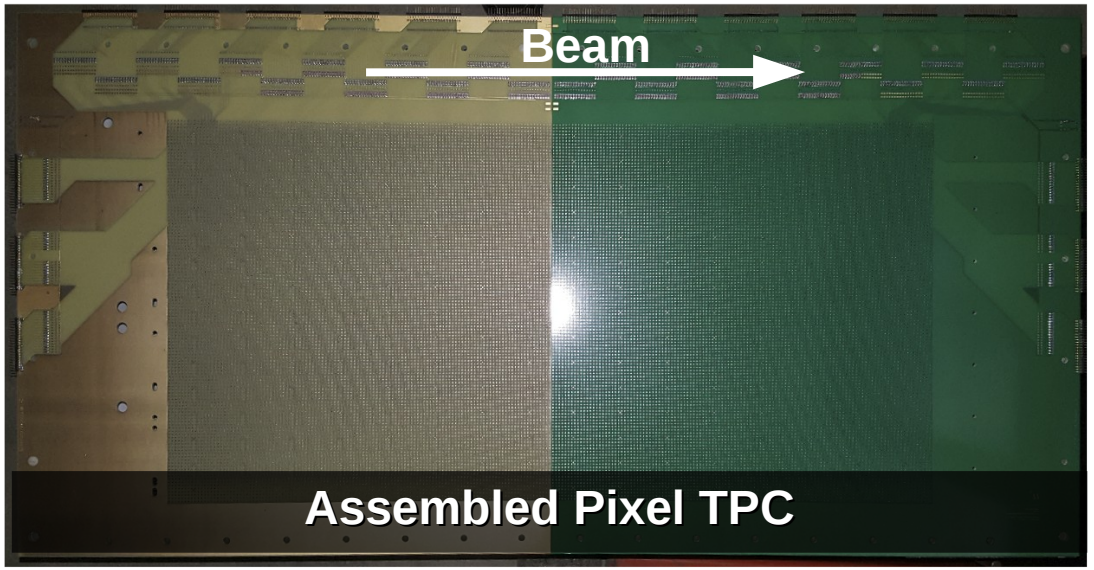



3mm Pixel TPC anode plane

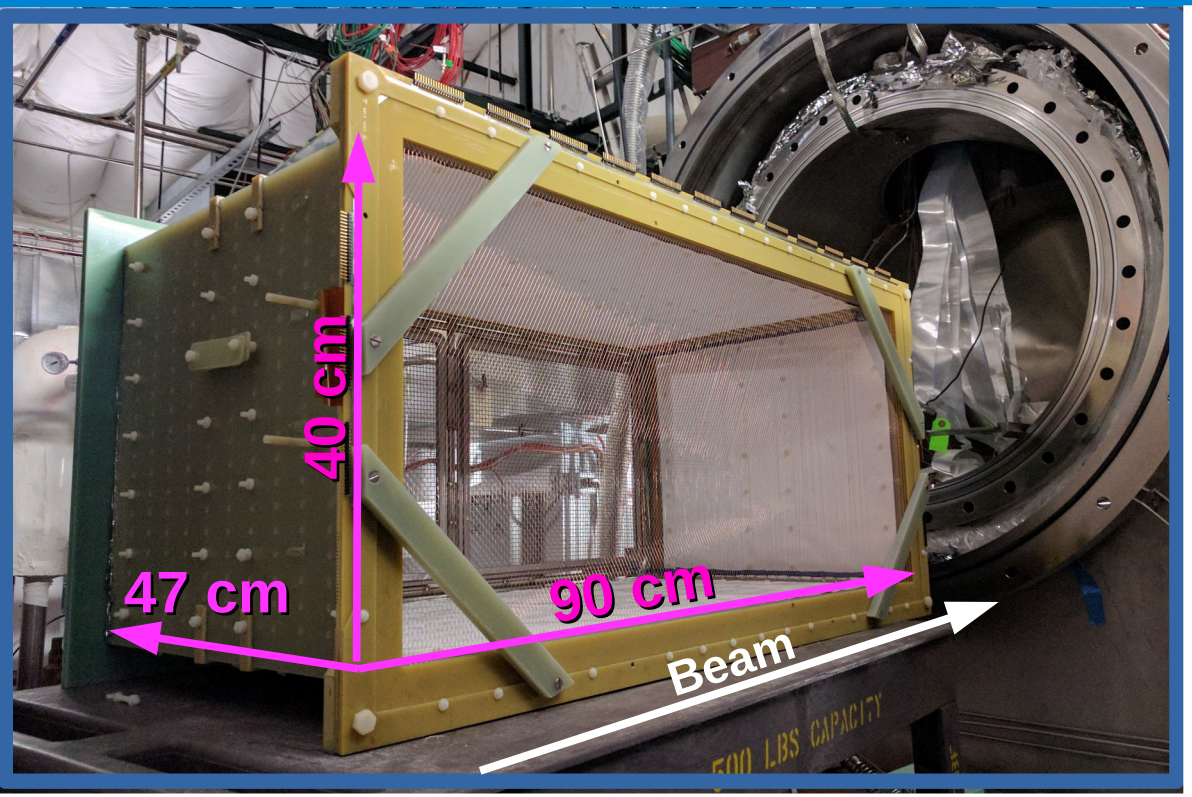
What is PixLAr?

- **The PCB board was manufactured by University of Bern in two parts**
  - Each PCB board has an active pixel area of 36 cm^2
  - 14,400 pixels per PCB board
    - 120 ROI's
  - Total pixel count is 28,800 pixels read out with 480 channels
  - Light detection devices reside on the upstream and downstream areas

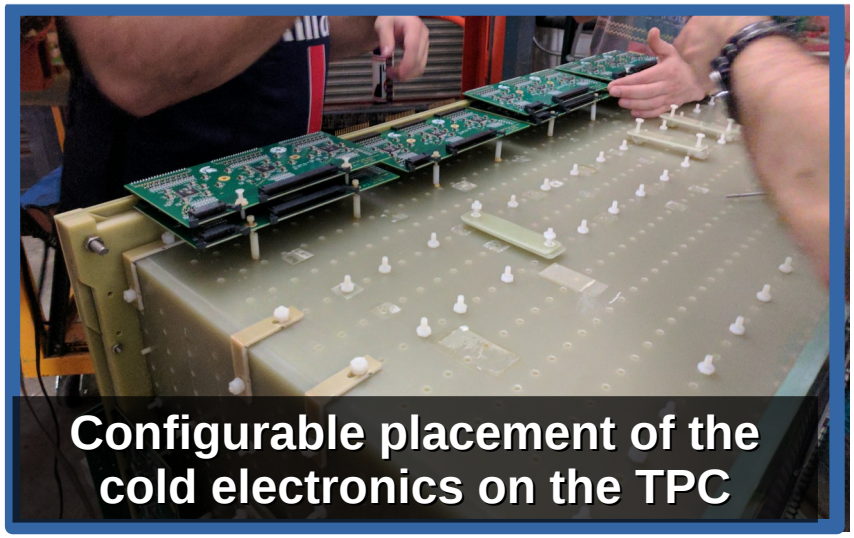




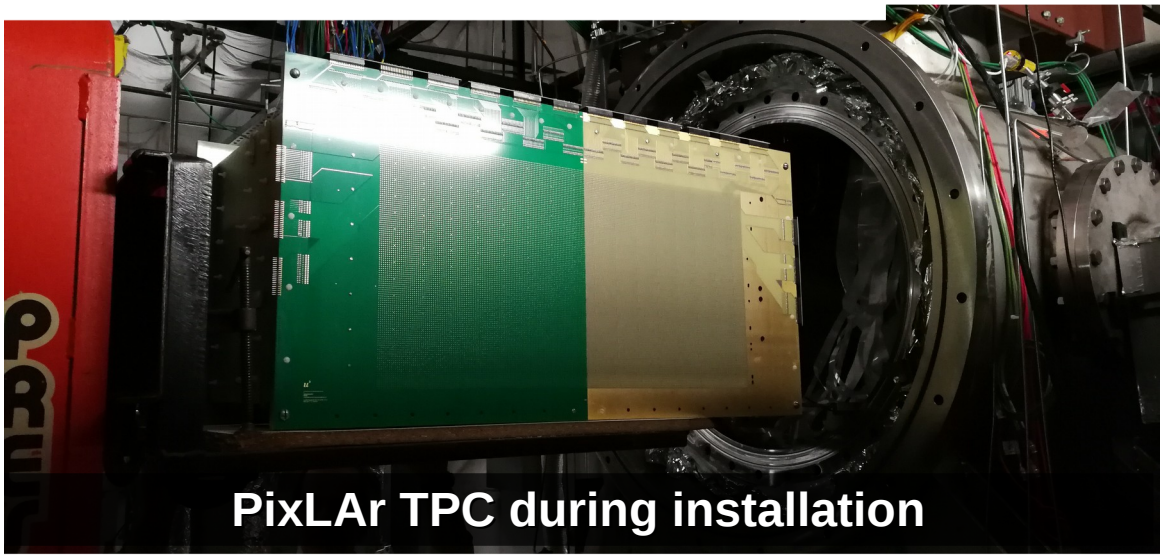
Inside the LArIAT Cryostat (TPC)



- **90 cm long (beam directions) 47 cm wide (drift direction) 40 cm tall TPC**
- **480 TPC channels available**
  - LArASIC's on custom motherboards (designed by MSU)
    - Same ASICs used by MicrBooNE
  - Output into CAEN 1740 digitizers
  - Great signal to noise achieved in all of our previous runs
- **500 V/cm nominal field**
  - Have operated well above and below this for various studies (no HV problems)



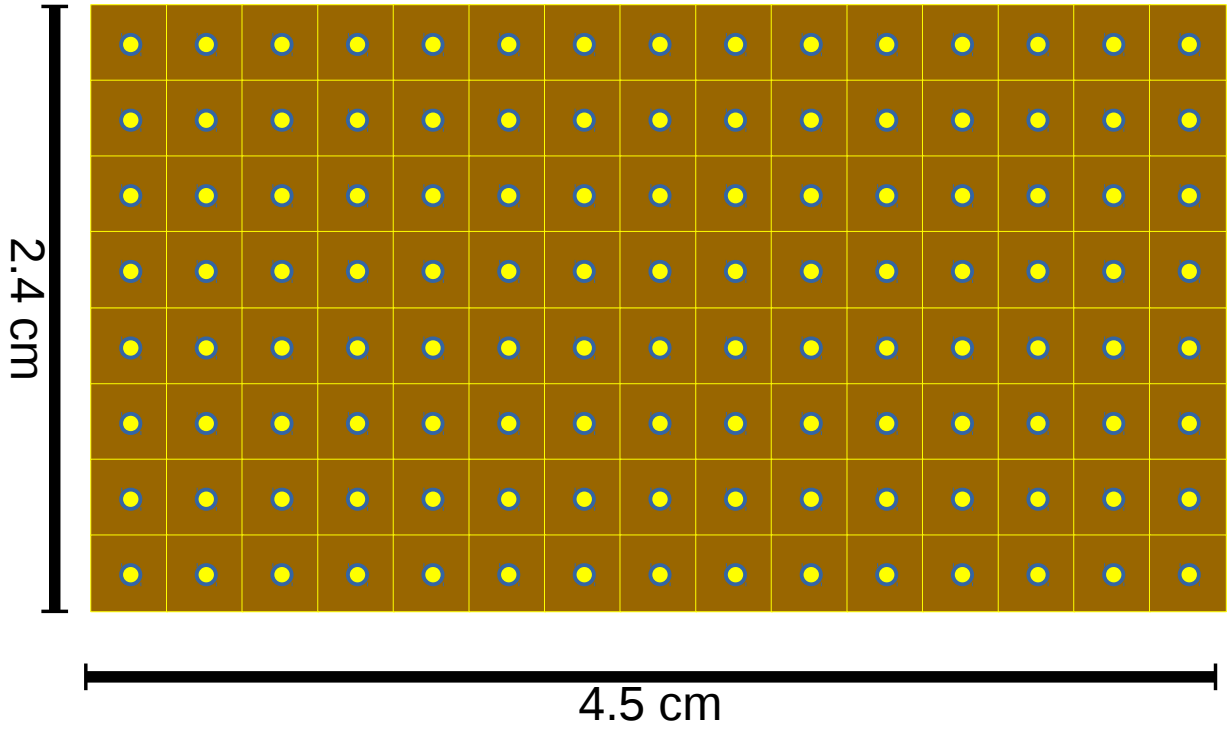
Configurable placement of the cold electronics on the TPC



PixLAr TPC during installation

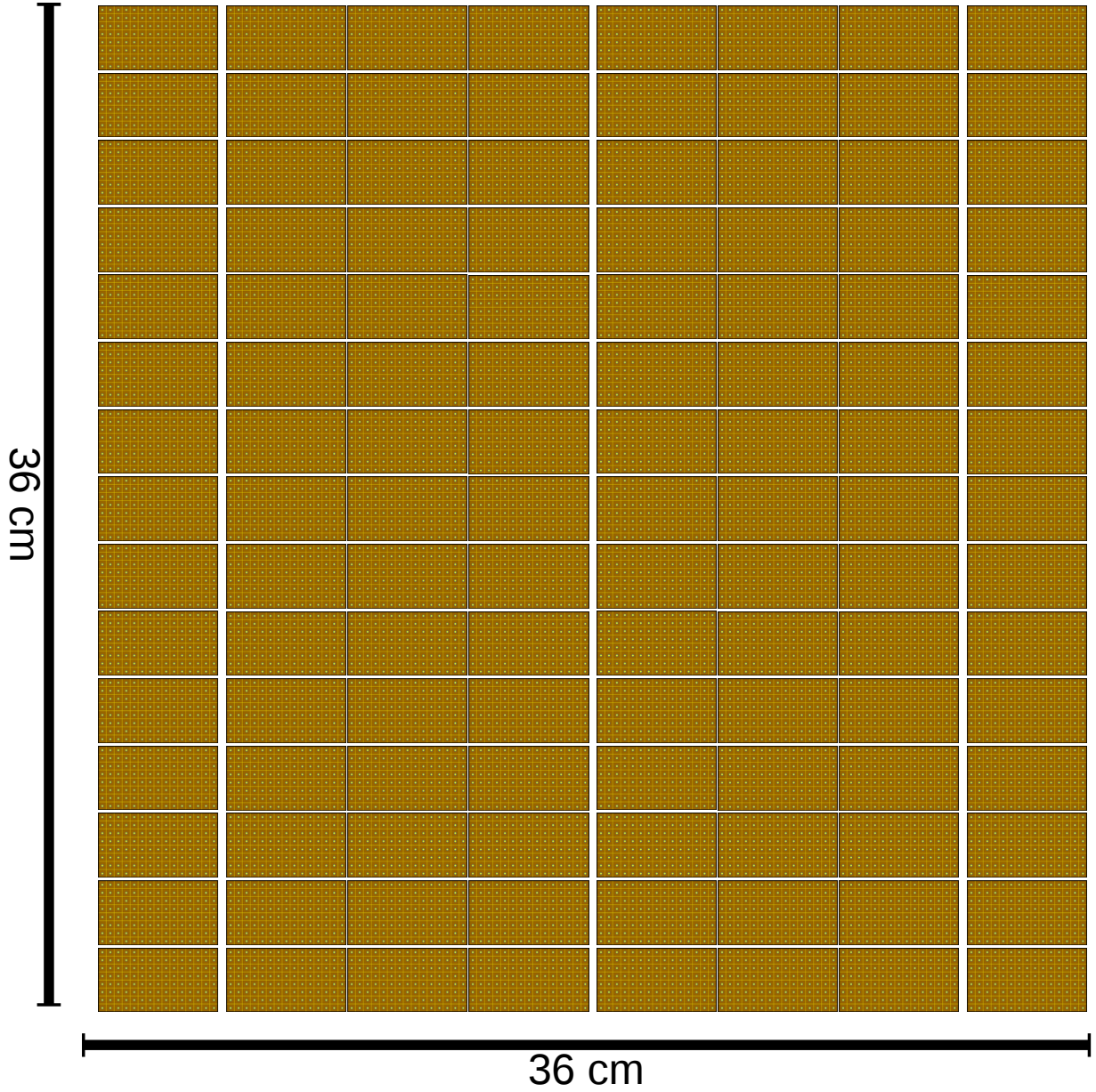
How to get 28k pixels with 480 channels

- **In PixLAr we have 120 pixels in an 8 x 15 array (Region of interest) with 3mm between each pixel**



How to get 28k pixels with 480 channels

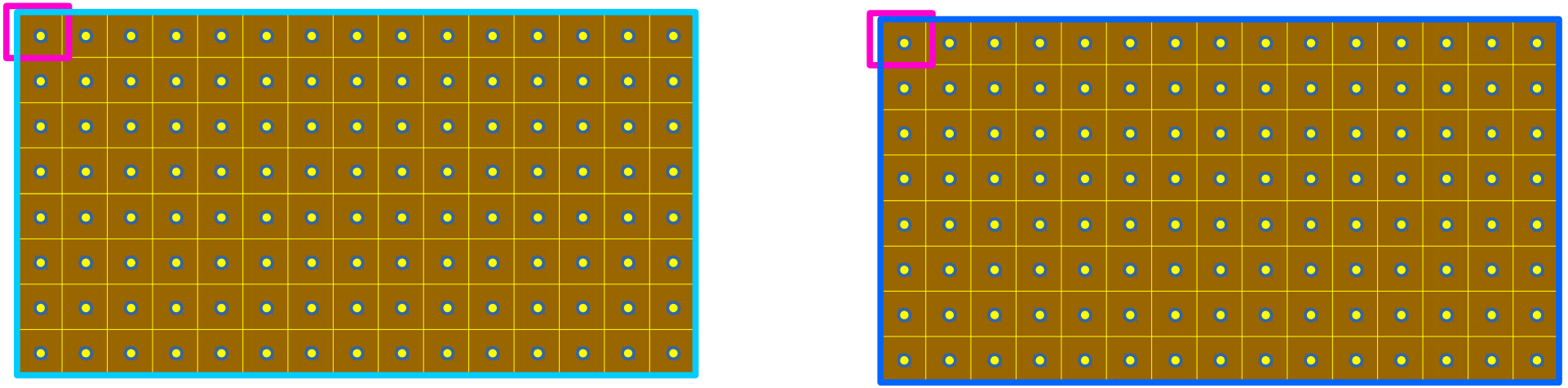
- **The pixel region gets duplicated in 8 x 15 array of ROI's to make up either the upstream or downstream pixel array**



How to get 28k pixels with 480 channels

- **On any ROI “Channel 0” is the same and goes to the same ASIC channel**
- **However, the ROI inductive trace goes to a unique channel**
  - “ROI 0” goes to ASIC channel 121
  - “ROI 1” goes to ASIC channel 122
  - and so on....
- This allows you to reconstruct each pixel and its neighbors uniquely based on matching the ROI in time with the pixel activity

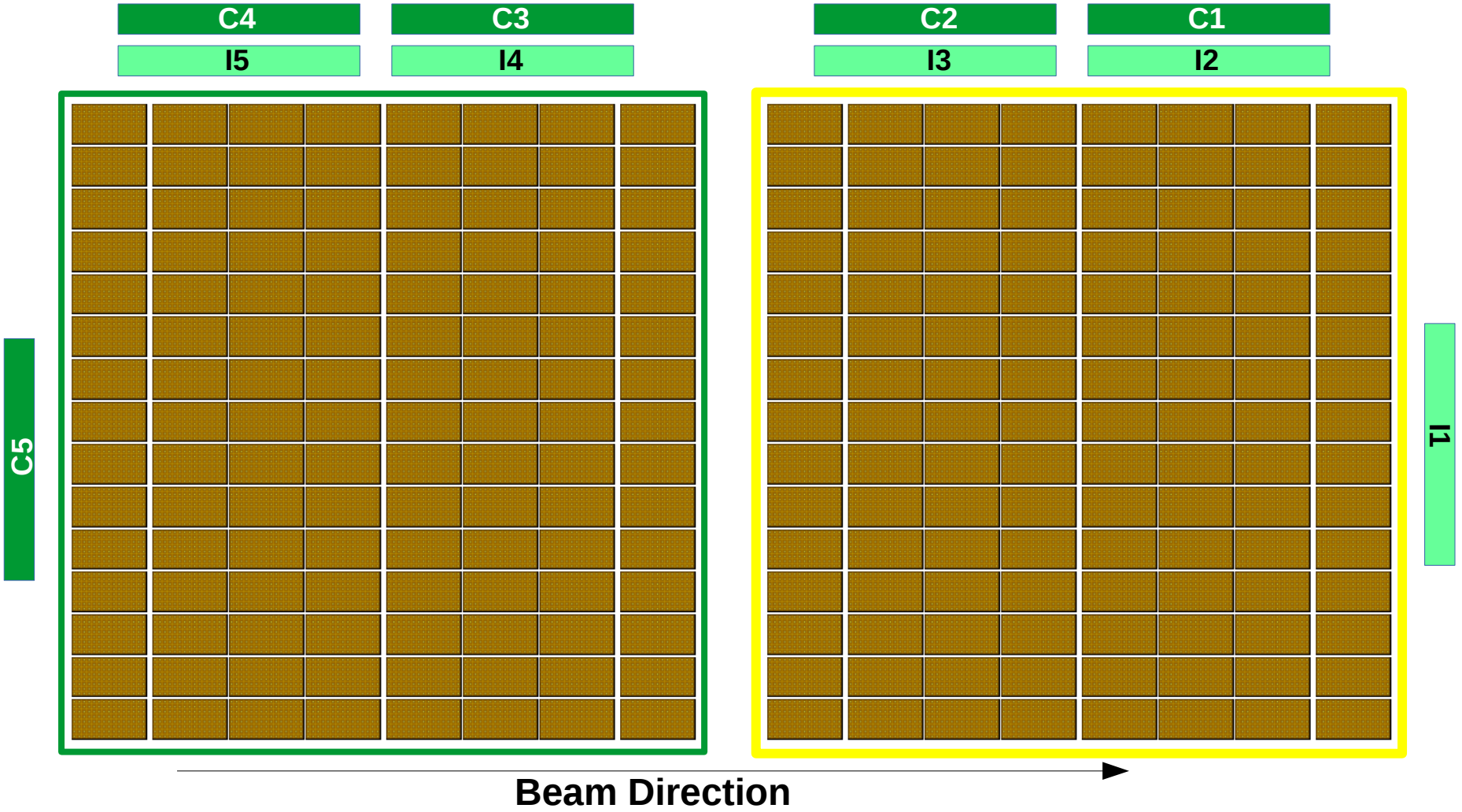
Each of these pixels goes to the same ASIC channel

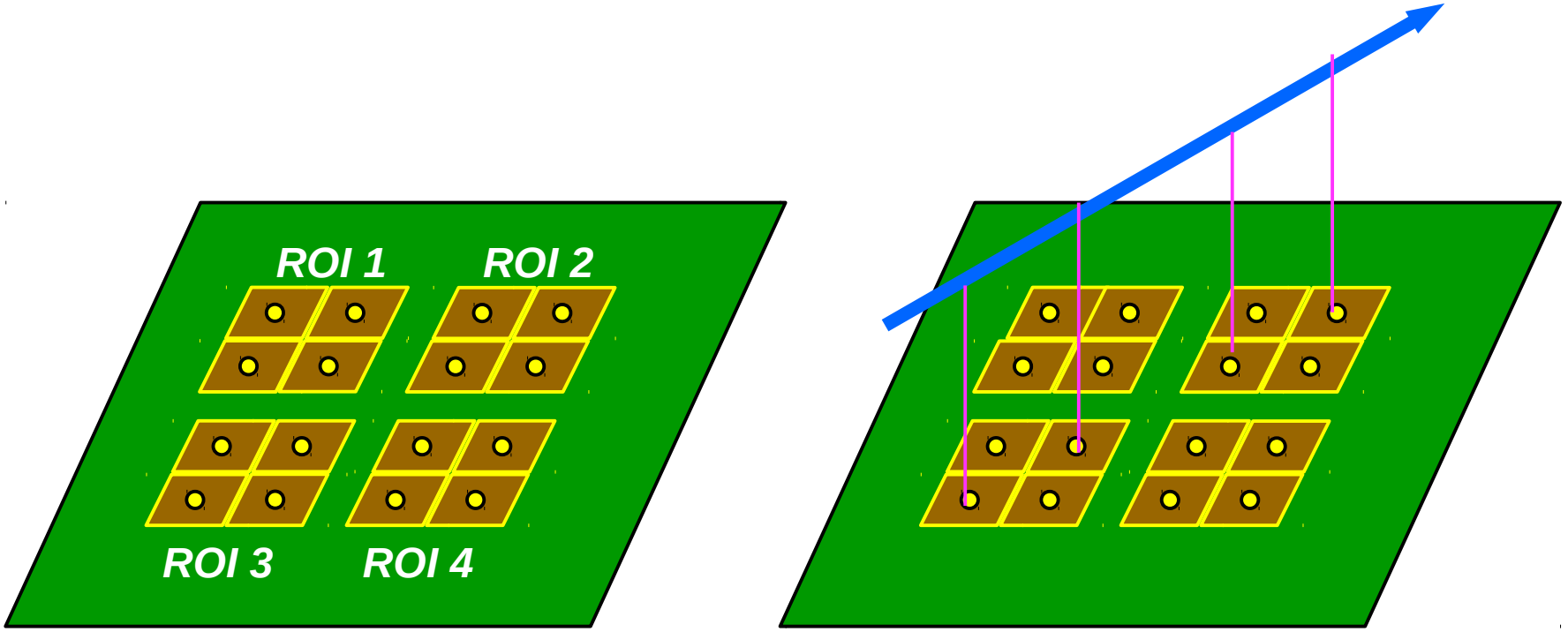


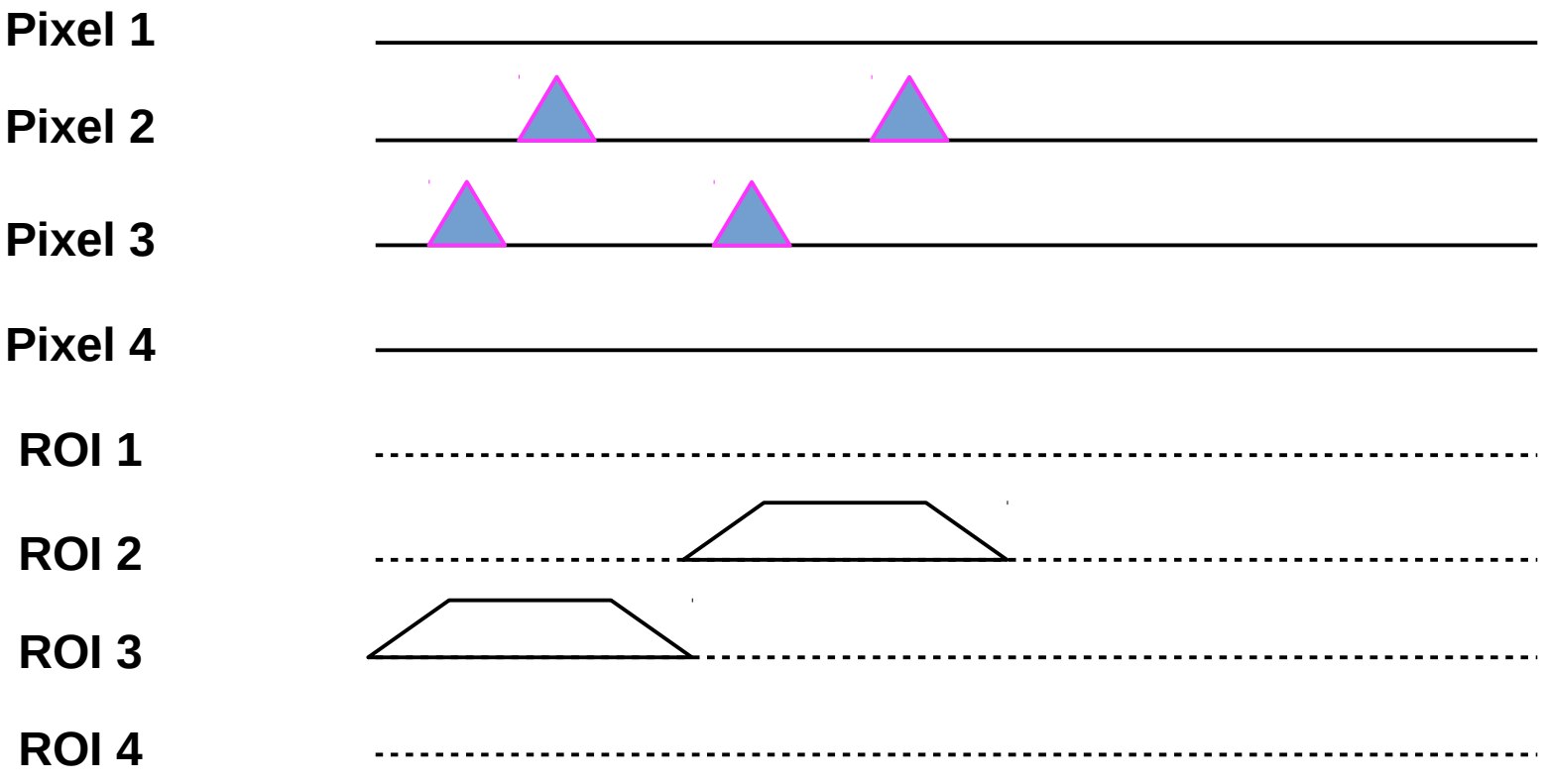
But each ROI region goes to a unique channel

How to get 28k pixels with 480 channels

- **Now we can use the LArIAT channel mapping (which tells us what boards corresponds to what DAQ channel ID (a unique number between 0 and 480) and what Pixel / ROI we are mapped to**

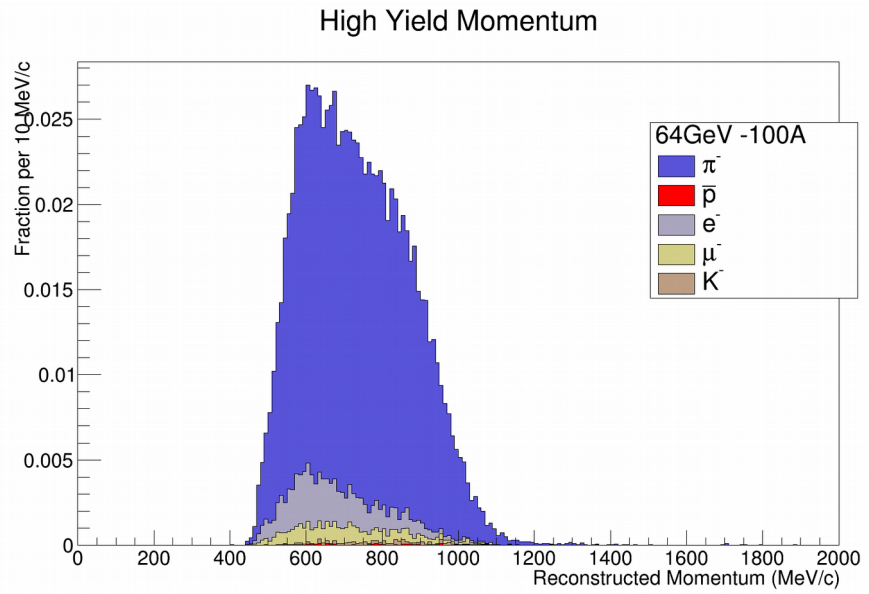


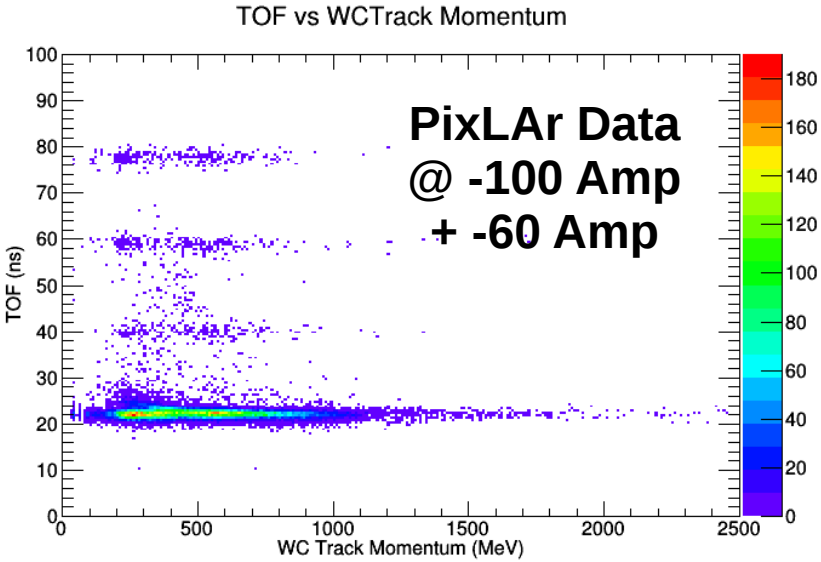

ROI 1
ROI 2
ROI 3
ROI 4


Pixel 1
Pixel 2
Pixel 3
Pixel 4
ROI 1
ROI 2
ROI 3
ROI 4

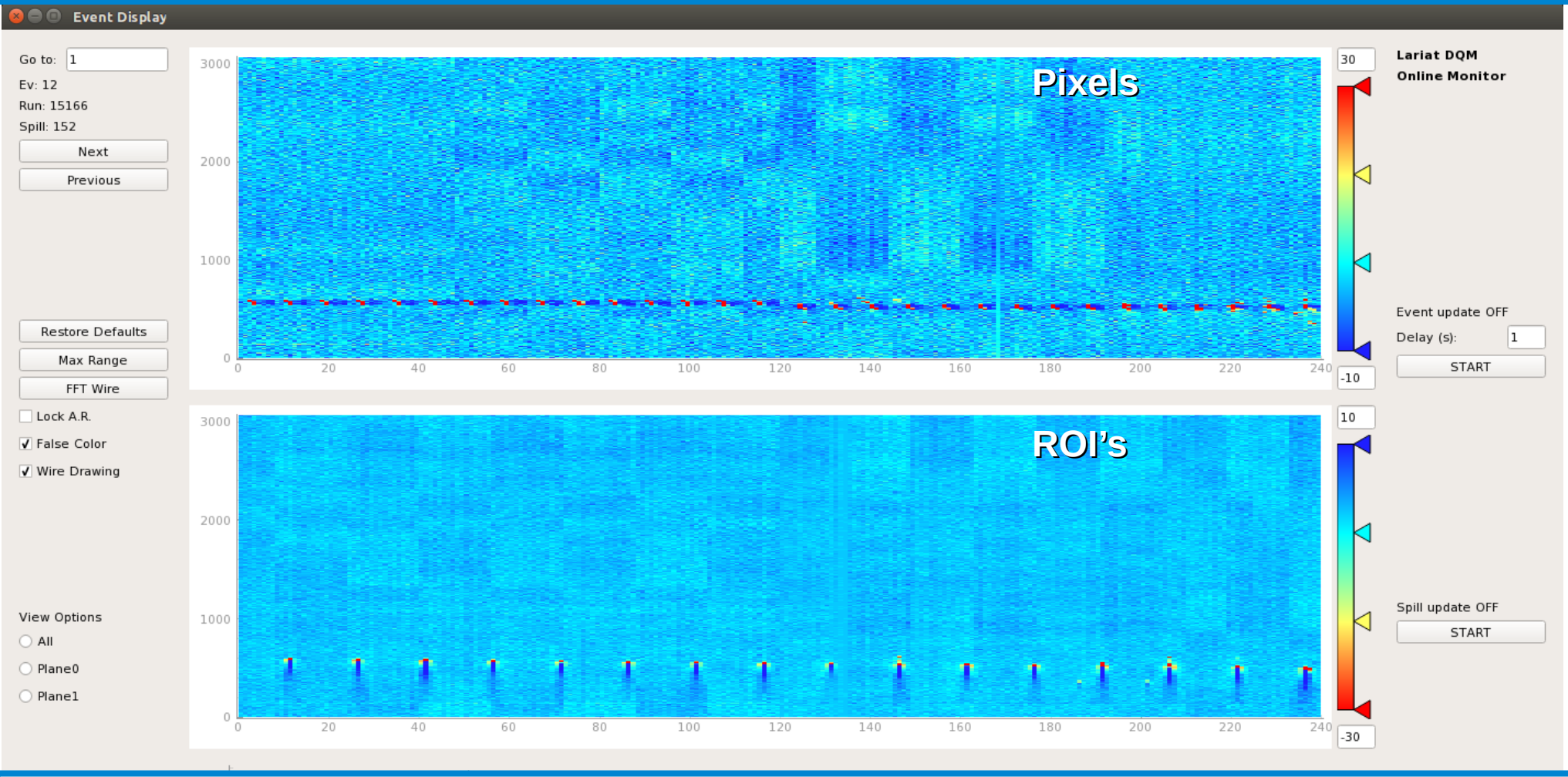
PixLAr Data Taking Campaign

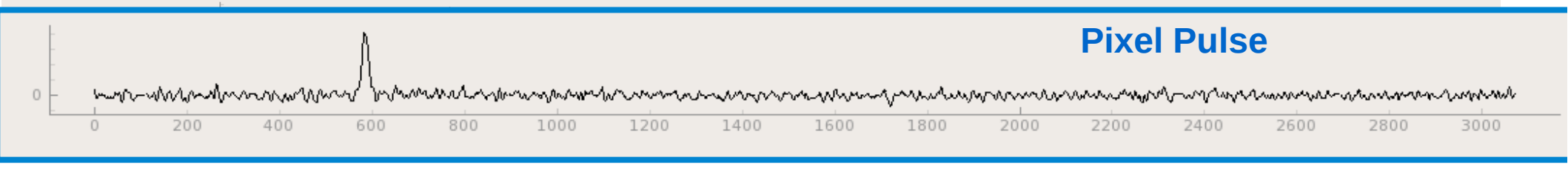
- **PixLAr took data from 12/1/17 – 1/25/18**
  - 7 weeks of data taking in a number of different beamline configurations
    - Both magnet polarities and at low and high momentum
  - Also triggered on cosmic rays using LArIAT cosmic paddles
    - Provides a nice sample of tracks which cross anode to cathode to help with calibrations and reconstruction

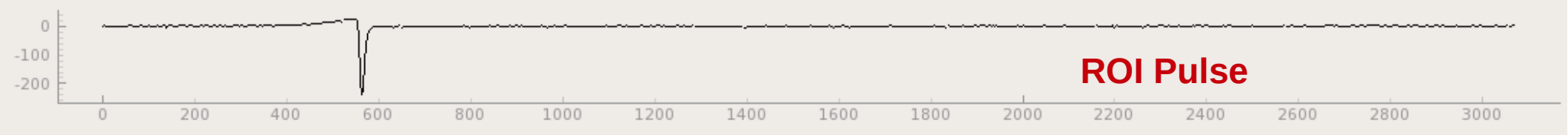


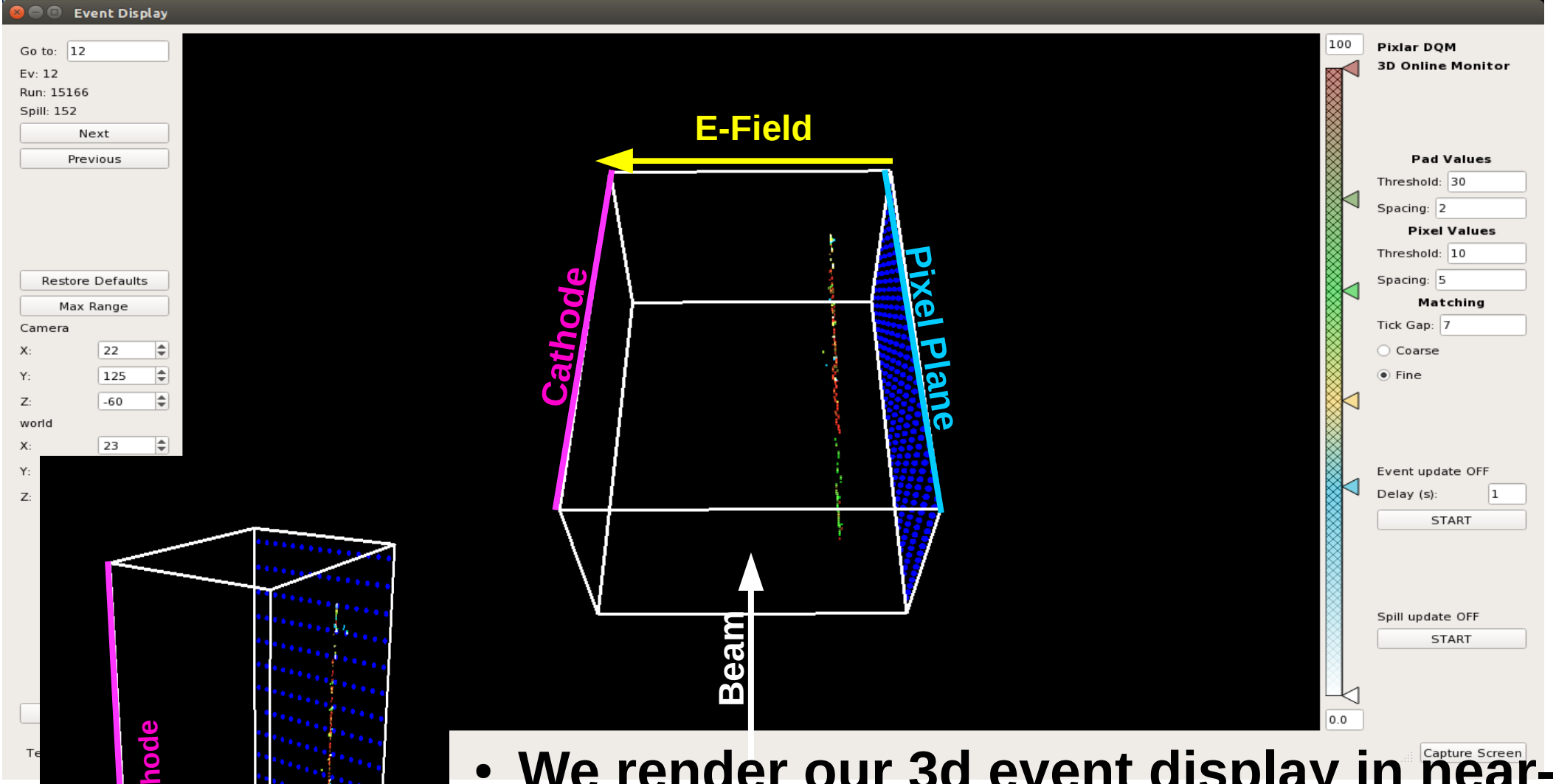


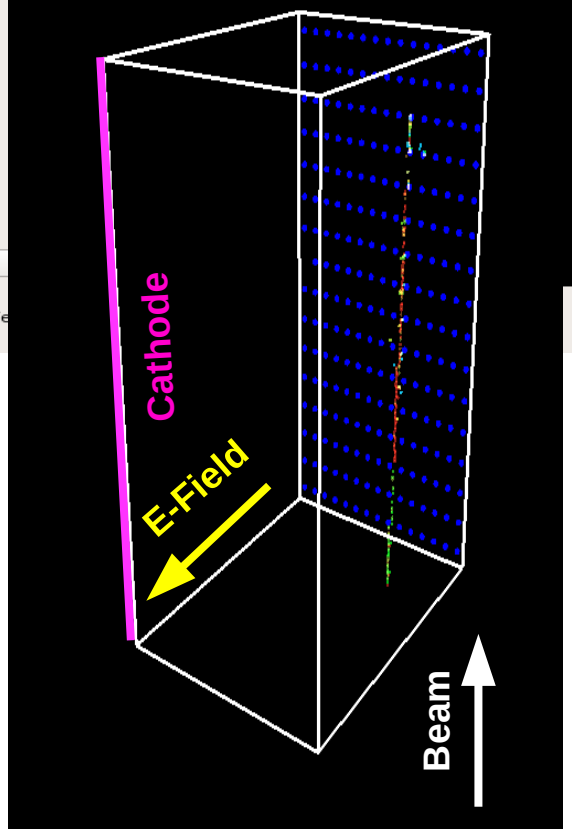
Pixel / ROI Event Display





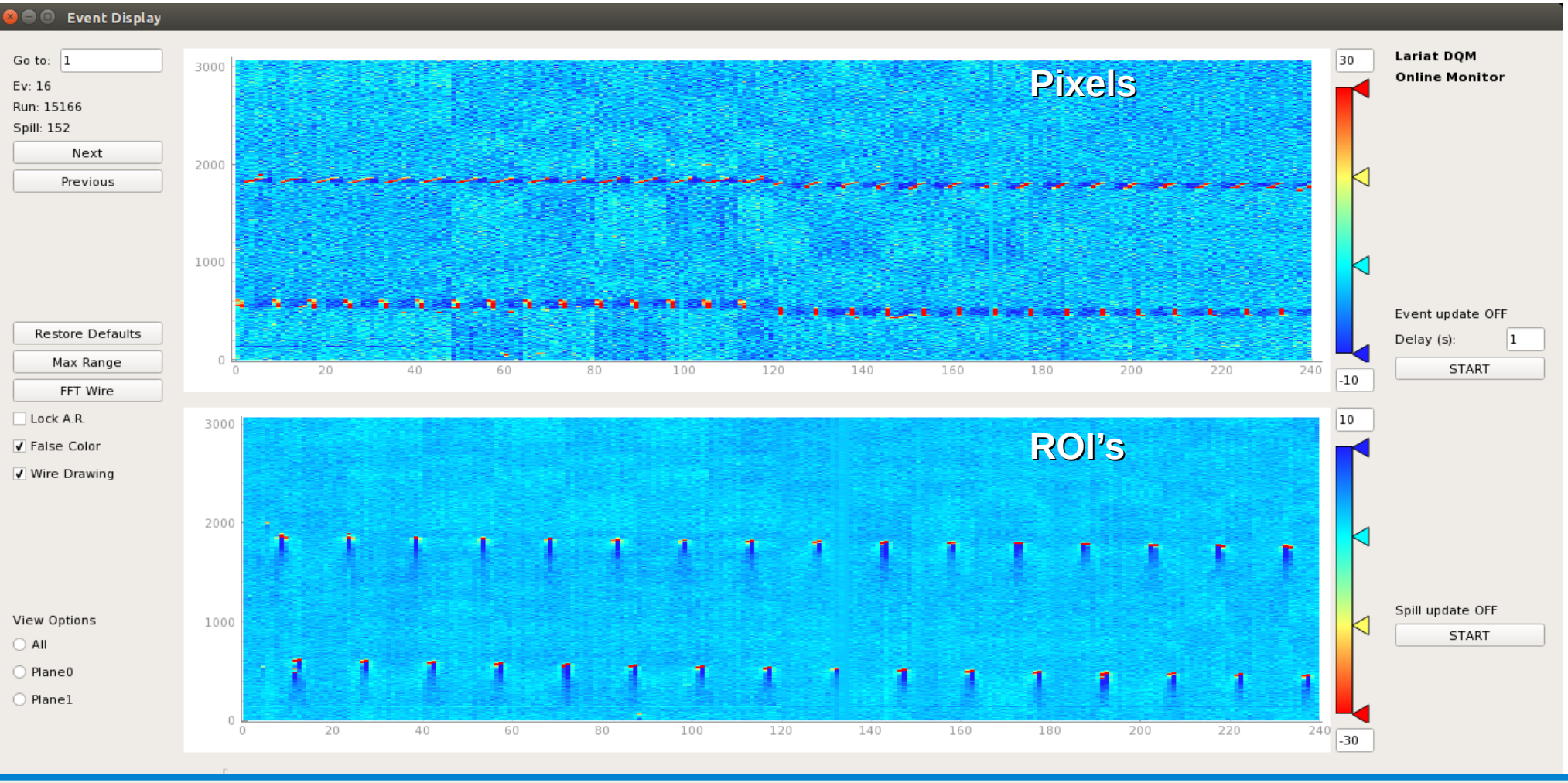


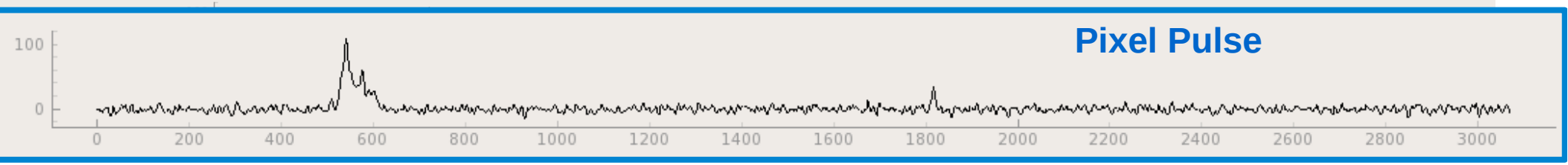


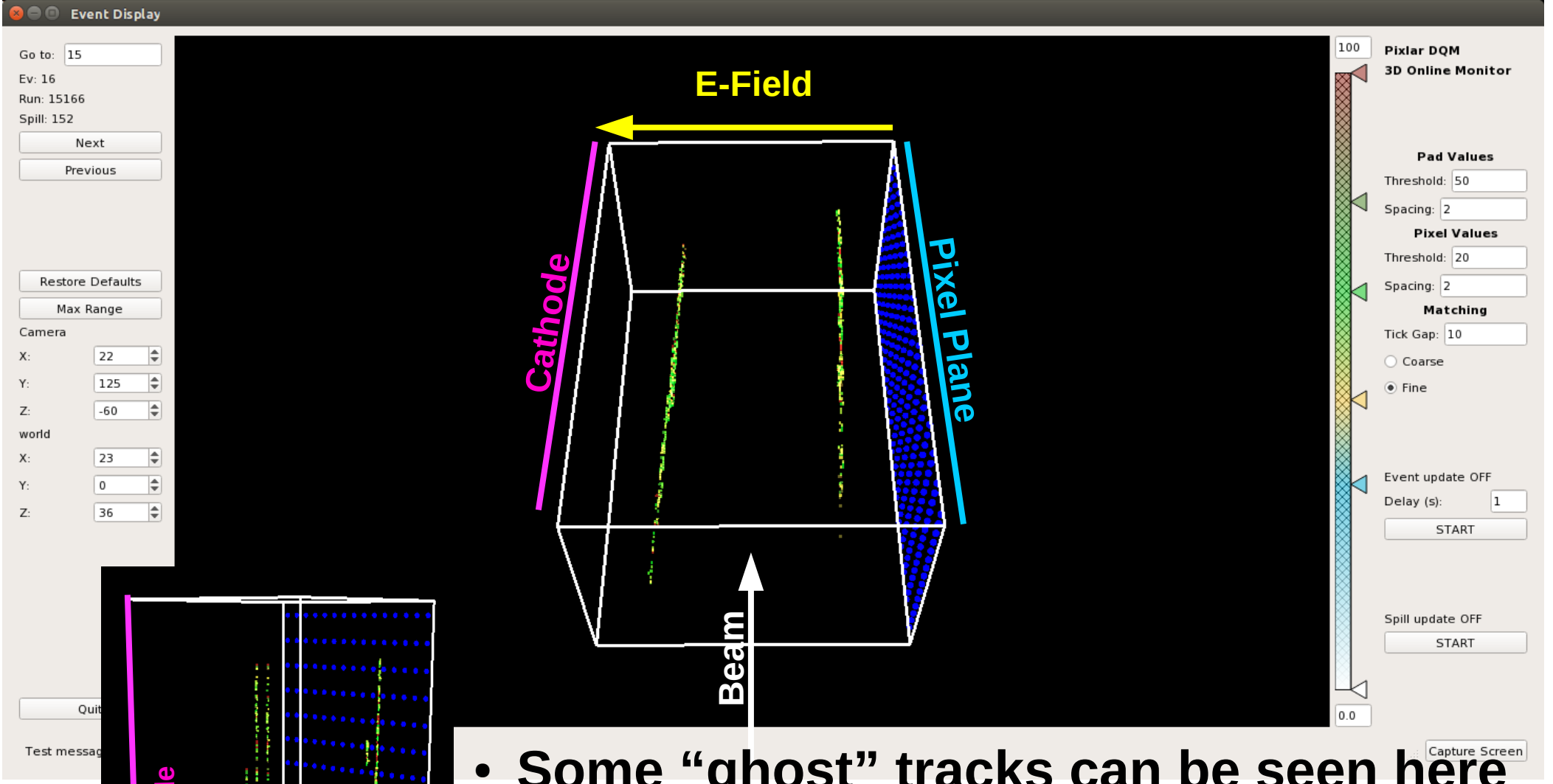


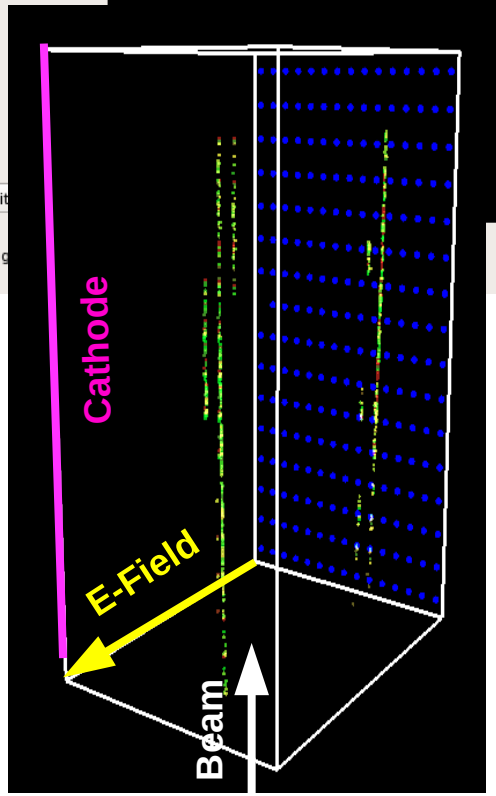
- **We render our 3d event display in near-real time (~1 min lag behind the DAQ to process the event)**
- **Here Pixel/ROI matching has been done**
  - For speed we typically only plot the ROI block

Pixel / ROI Event Display (Two track event)



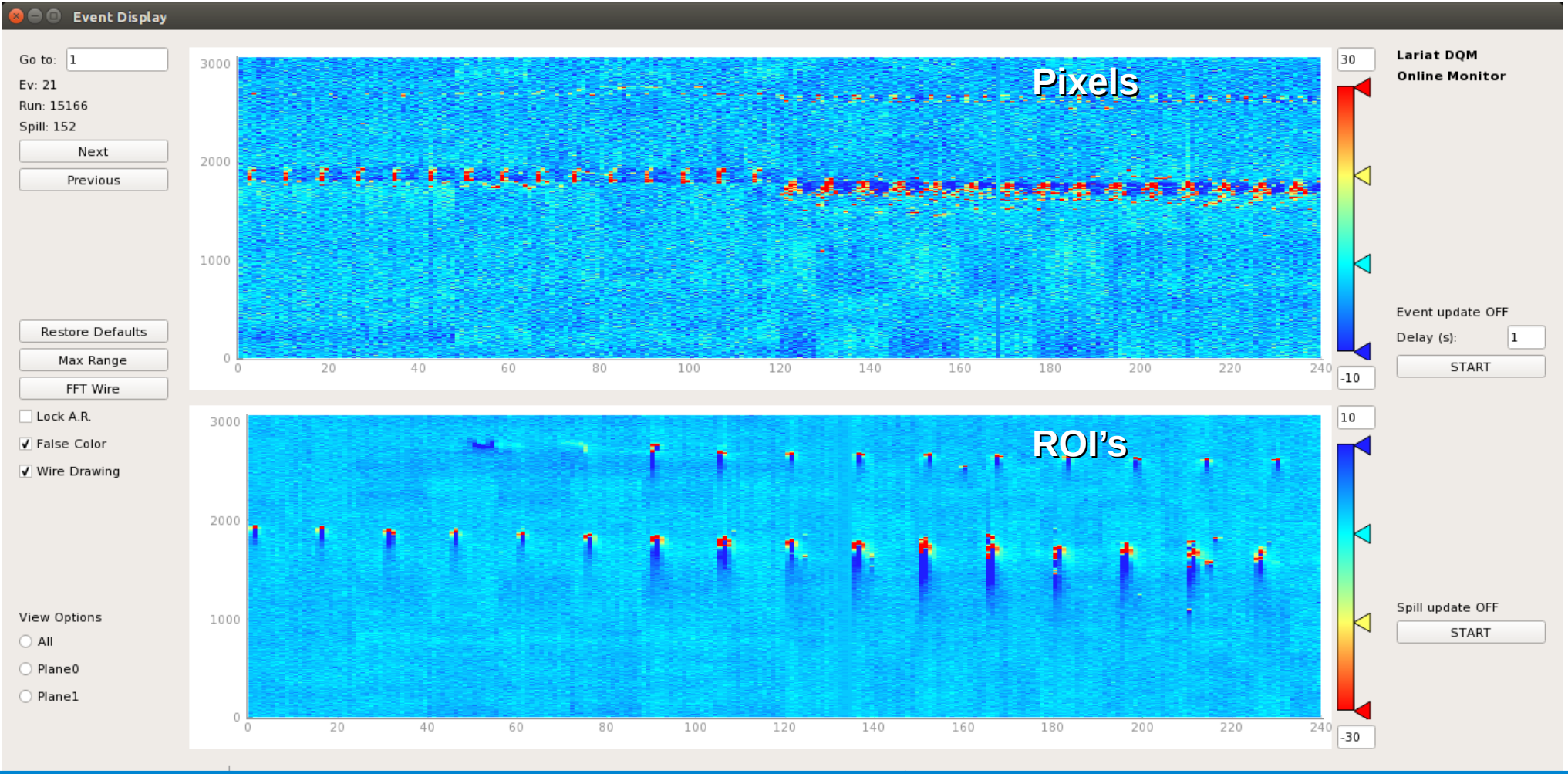


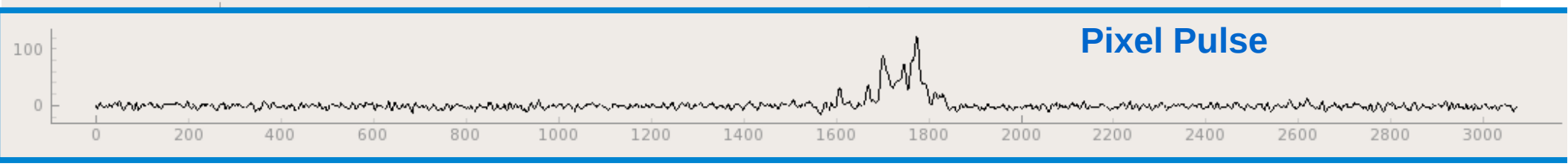


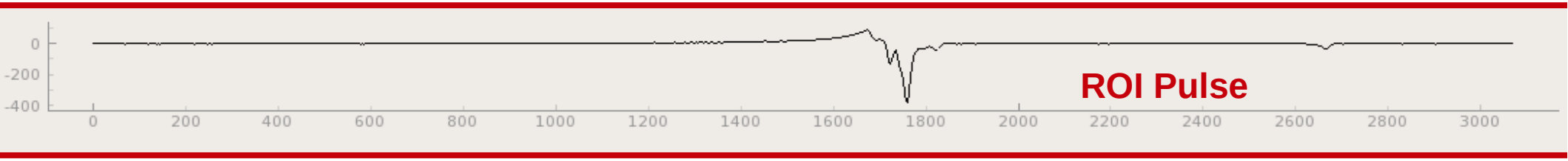


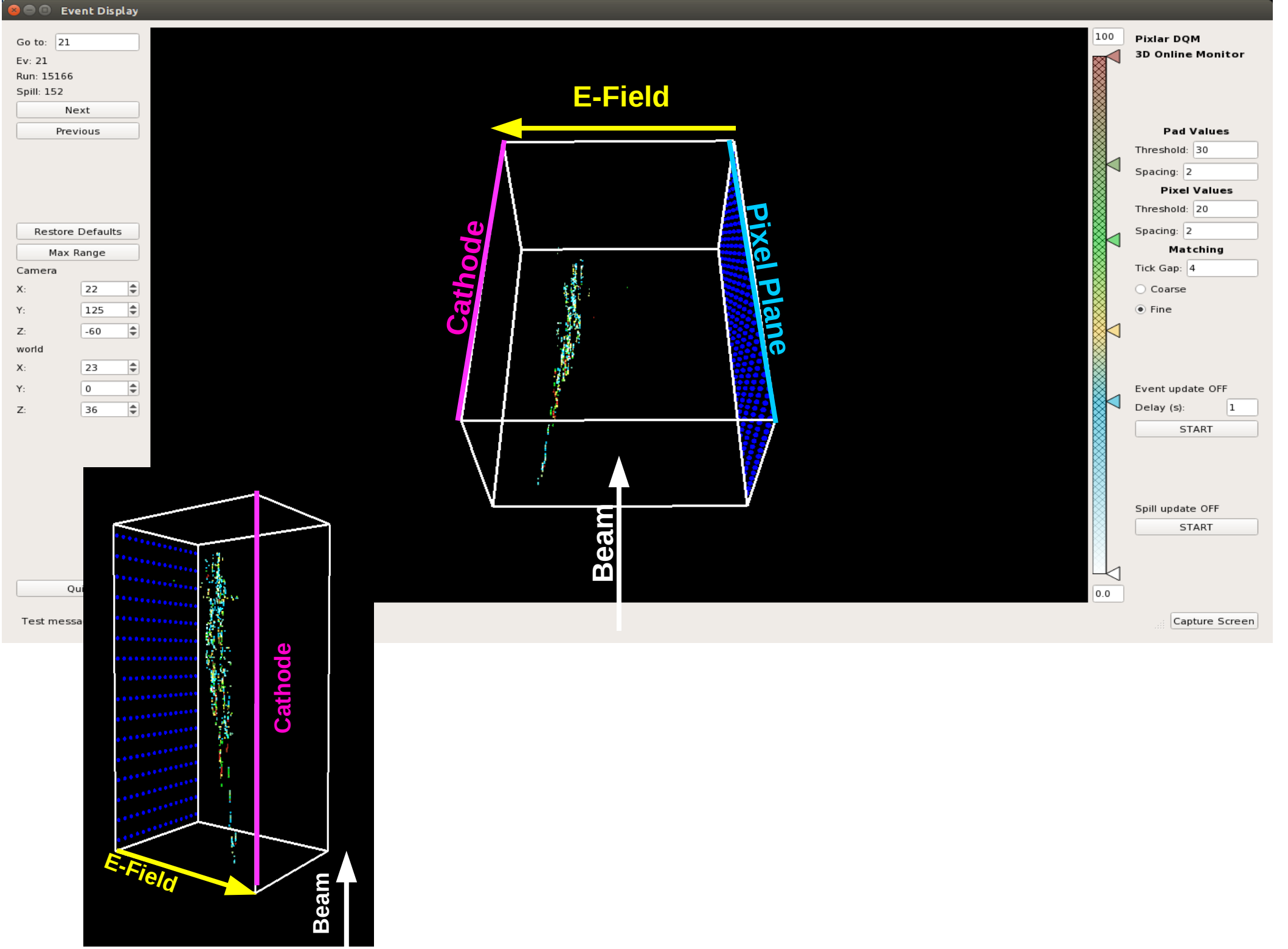
- **Some “ghost” tracks can be seen here**
  - Note: only the most rudimentary peak/hit finding is done “on the fly” to generate these events
  - More strict matching requirements tends to clean this up

Pixel / ROI Event Display (EM-Shower)



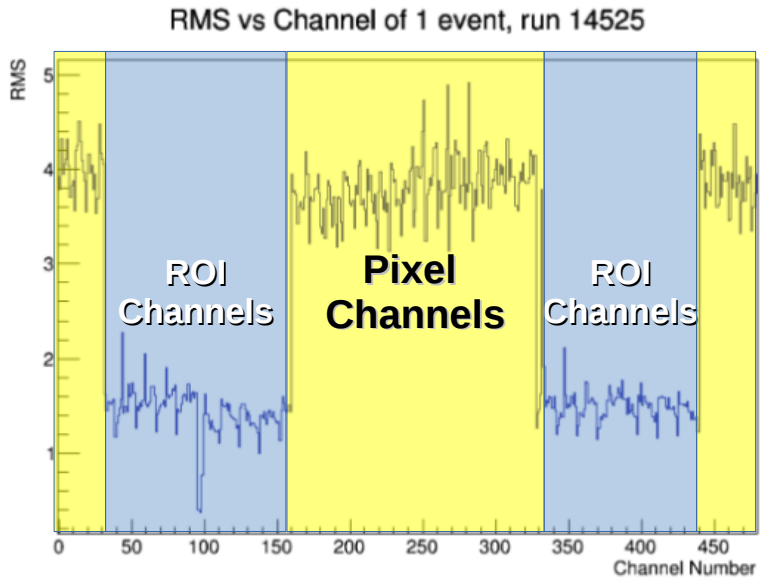


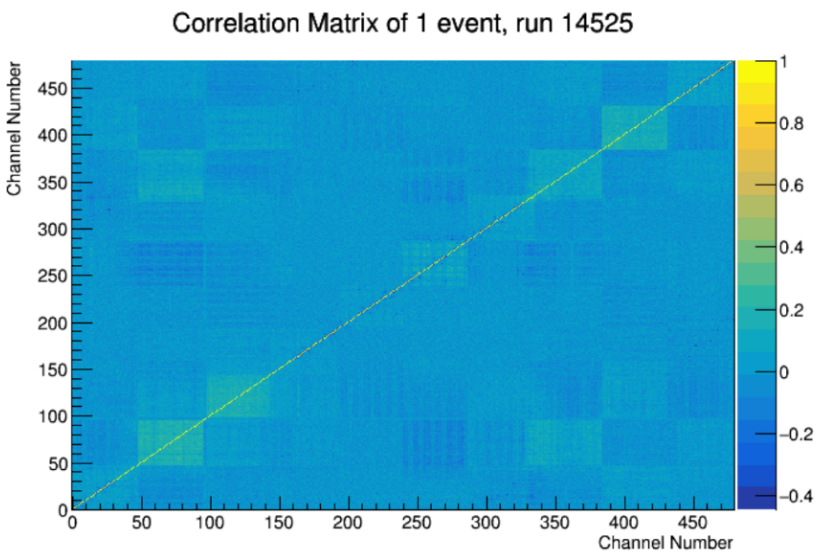



Event Display
Go to: 21
Ev: 21
Run: 15166
Spill: 152
Next
Previous
Restore Defaults
Max Range
Camera
X: 22
Y: 125
Z: -60
world
X: 23
Y: 0
Z: 36
Qui
Test messa
E-Field
Cathode
Pixel Plane
Beam
100
0.0
Pixlar DQM
3D Online Monitor
Pad Values
Threshold: 30
Spacing: 2
Pixel Values
Threshold: 20
Spacing: 2
Matching
Tick Gap: 4
Coarse
Fine
Event update OFF
Delay (s): 1
START
Spill update OFF
START
Capture Screen
Cathode
E-Field
Beam

TPC Performance

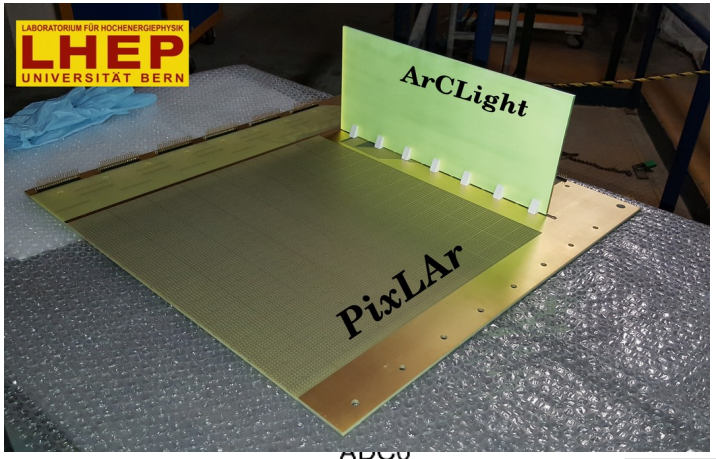
- **Low level of noise seen in the TPC**
  - Pixels RMS ~ 4 ADC
  - ROI RMS ~ 1.5 ADC
  - Not much in the way of coherent noise or cross-talk either
- **Using a small sample of through going tracks typical pixel Signal-to-noise ~10:1**
  - This was estimated using a small sample of hand-scanned events where the typical MIP looking track had ~ 40 ADC peak
  - More robust analysis of this just getting underway

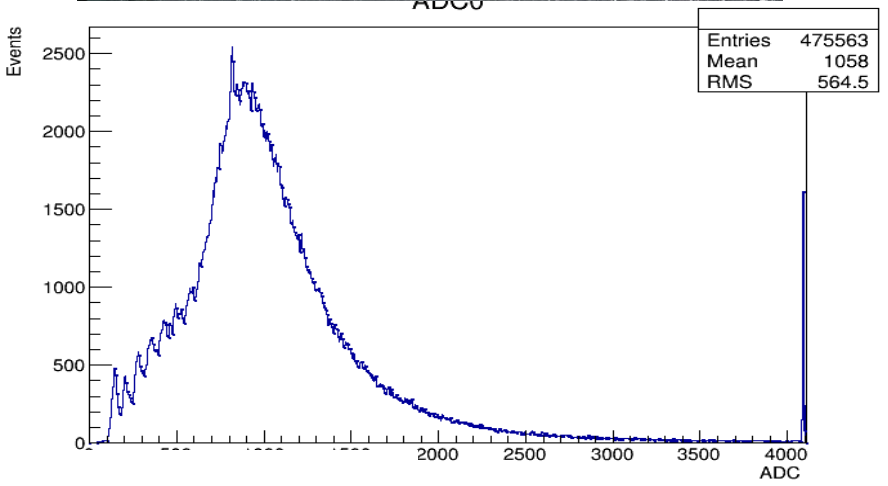


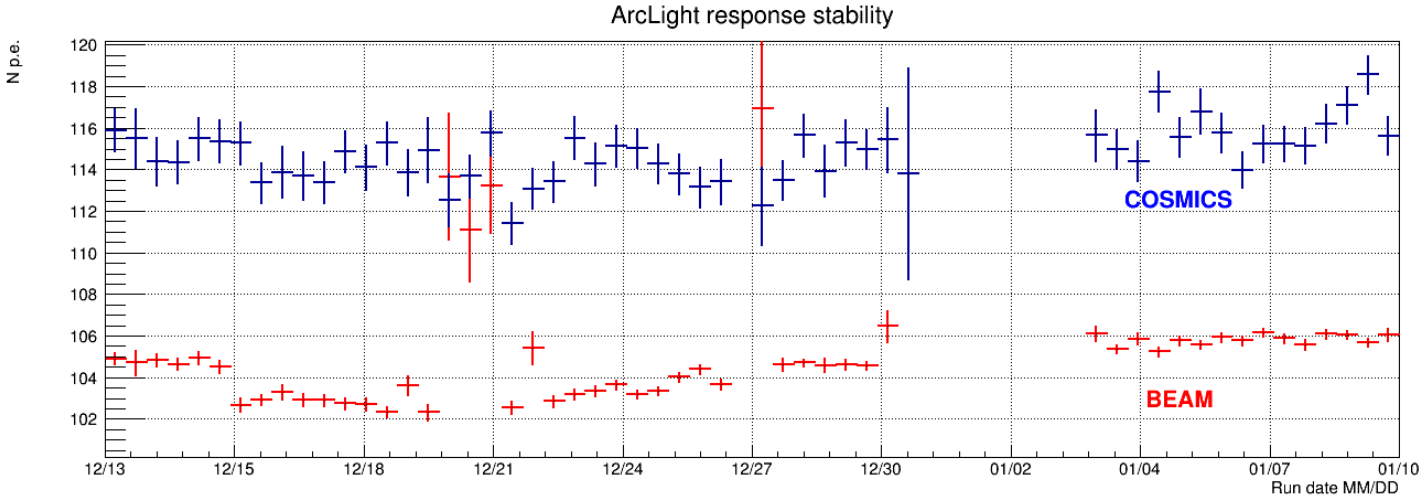


ArcLight Performance

- **4 out of 8 SiPM's worked**
  - Not clear what caused the other 4 to lose response
- **Single PE response seen in both beam and cosmics**
  - Very preliminary photon detection efficiency ~0.24%
    - Expected ~0.35%
    - Work still ongoing….
- **ArcLight response has been stable over the course of our run**

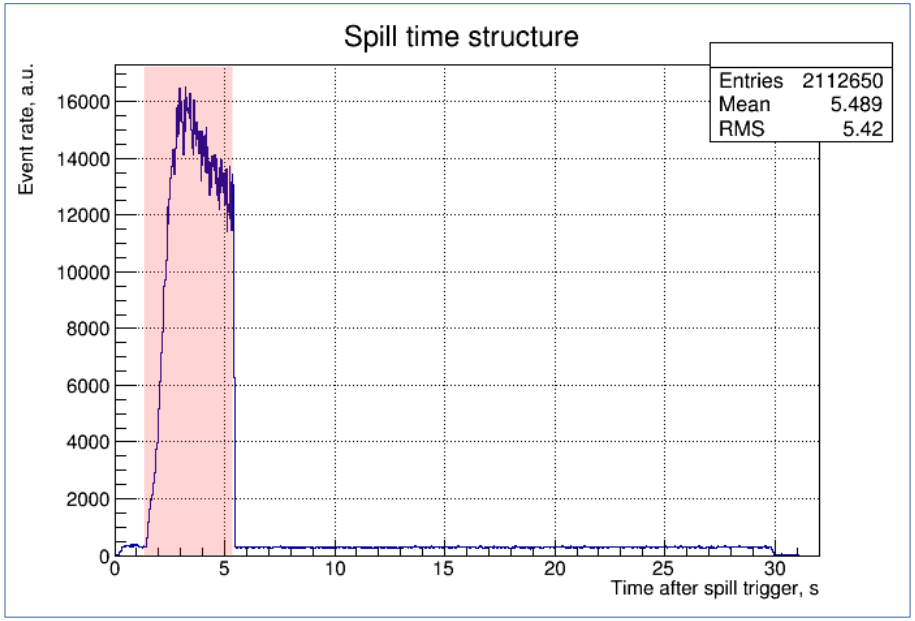


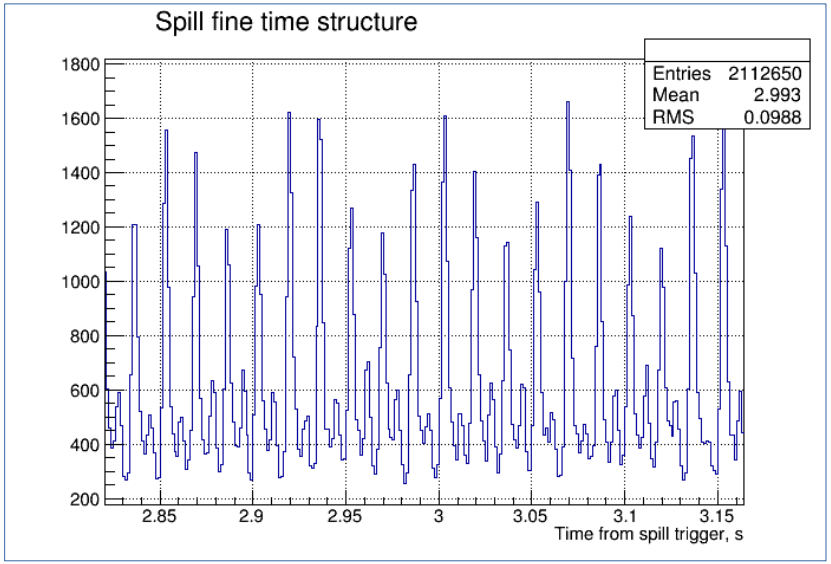


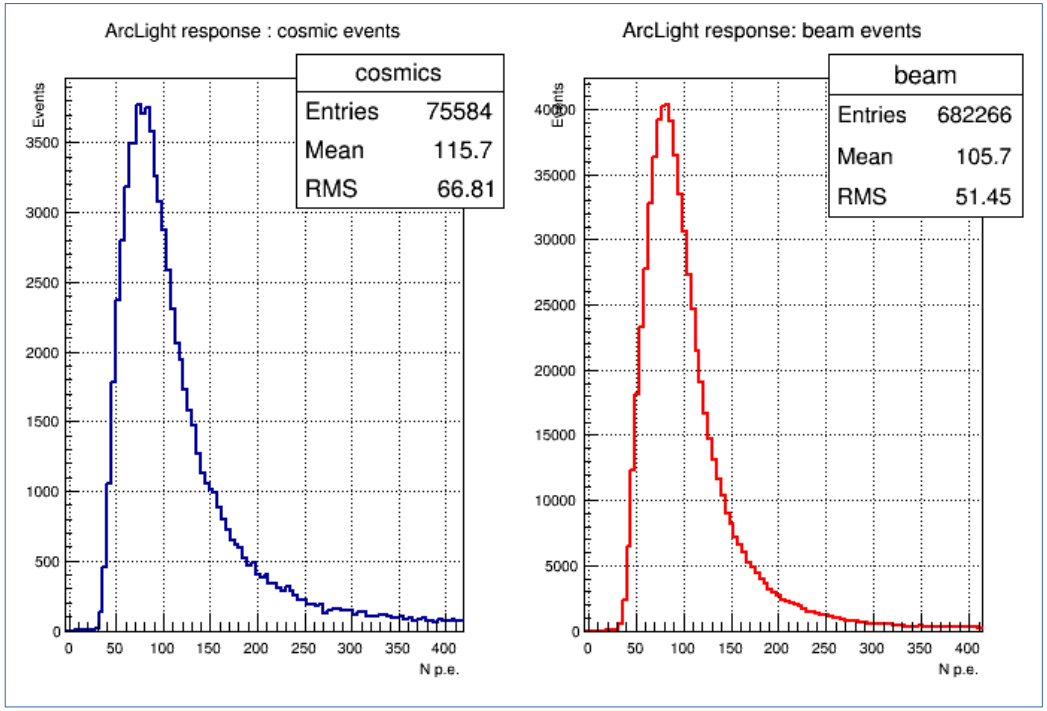


ArcLight Performance

- **Using the timing information from the ArcLight, the beam spill structure becomes apparent!**
- **Light Yield for both beam and cosmics is very consistent**







Arapuca's Performance

- **2 out of the 3 Arapuca's functioned very well during our run**
  - Coincident triggers clearly seen during cosmics run
  - For reasons not entirely clear, they were inducing an unusual amount of noise on the pixel plane, so we did not run with them on as much
- **Analysis is still underway, but will provide a nice cross-comparison with the ArcLight device**

Conclusions

- **PixLAr has just completed its test beam data taking**
  - We have a veritable treasure trove of interesting pixel LArTPC data in hand!
  - Will be working in collaboration with LArIAT to do some interesting cross-comparisions between the wire and pixel readout
    - Note: Since the hardware multiplexing was used for this setup, it isn't a true demonstration of the power of pixel readout...but a good step in that direction!
- **We were able to demonstrate immediate 3d display of our data in near real time**
  - More detailed reconstruction still to be done
- **Both the Arapuca's and ArcLight successfully took beam data during the run**
  - Combining the output of both these detectors should provide useful input to the ongoing LAr-Light readout R&D

Special Thanks

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Jason St. John (PI)

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Vincent Basque (Grad)

University of Sheffield, UK
Neil Spooner (PI)
Dominic Barker (Grad)

Stanford Linear Accelerator (SLAC)
Kazuhiro Terao
Yun-Tse Tsai

** and the many members of the LArIAT collaboration who helped out immensely during the PixLAr run just because they are good people!*